NOAA Earth System Research Laboratory

Blocking and the MJO in GEFS reforecasts: forecast skill and interactions

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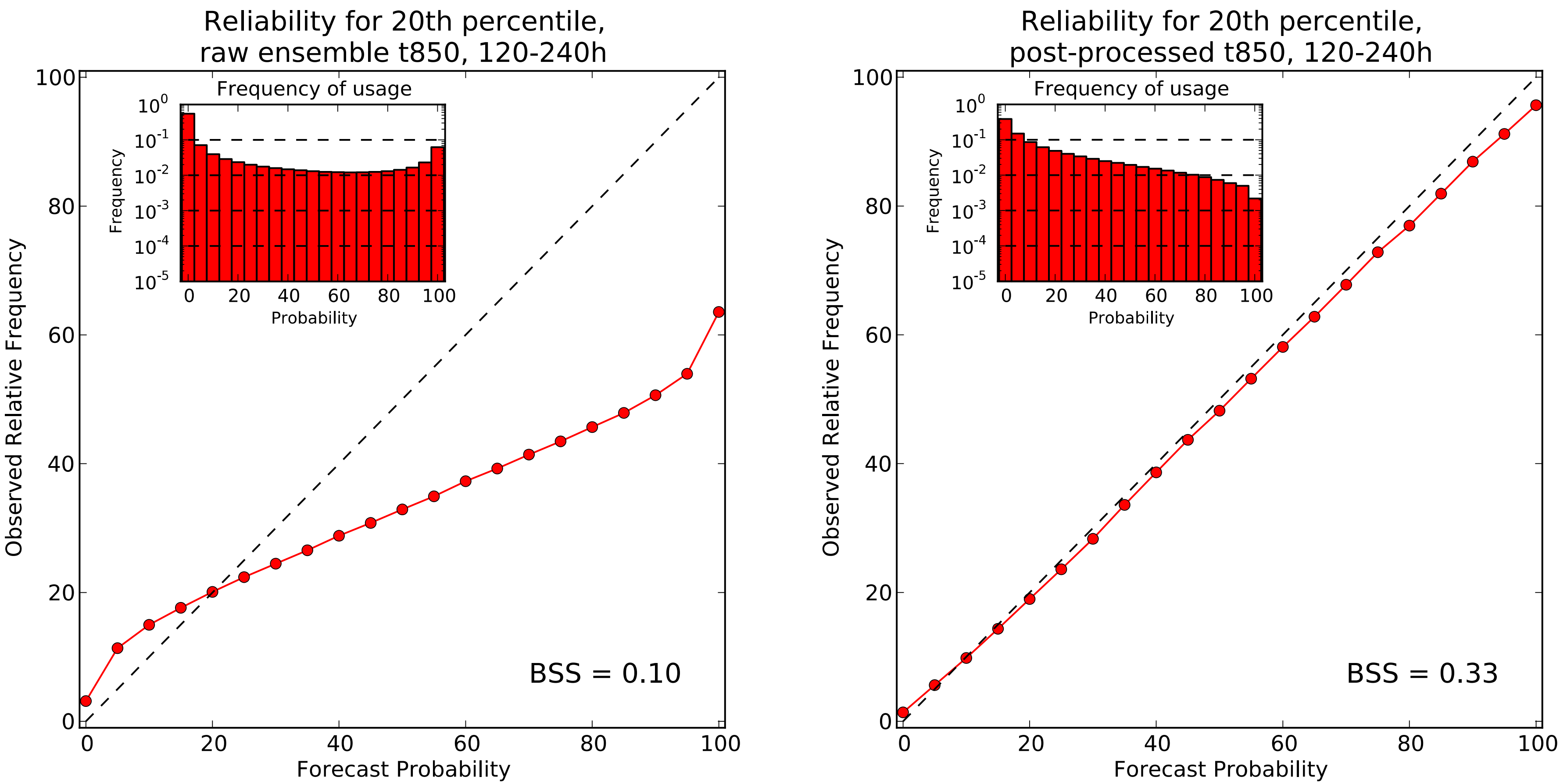
Our GEFS reforecasts were produced to facilitate statistical post-processing, and they do that.



Post-processing here of T850 for 5-10 day forecasts using non-homogeneous Gaussian regression algorithm of Gneiting et al. (2005). We feel this defines the state of the art for medium-range forecast products (a challenge: please try to beat our products).

Precipitation Forecast Products Based on NCEP GEFS Reforecasts, Version2

This page presents experimental precipitation forecasts, including deterministic and probabilistic forecast information produced with a rank-analog technique similar to the one described in Hamill and Whitaker (2006). It also presents graphical forecast products similar to ECMWF's Extreme Forecast Index. More detailed information on both is available here.

These forecasts will usually (but not always) be updated by 14 UTC each day. They likely will not be available as consistently as operational products from the National Weather Service. Also please note that this is an experimental forecast product, and is not an official forecast of NOAA or its National Weather Service. Precipitation units are mm (25.4 mm = 1 inch).

We welcome feedback on this product. Email comments to: esrl.psd.reforecast2@noaa.gov .

Choose a Forecast Plot Below:

Analysis Date *(format: yyyymmdd)*:

Please input a date within last 7 days: 20130708 Latest: Jul 8 2013

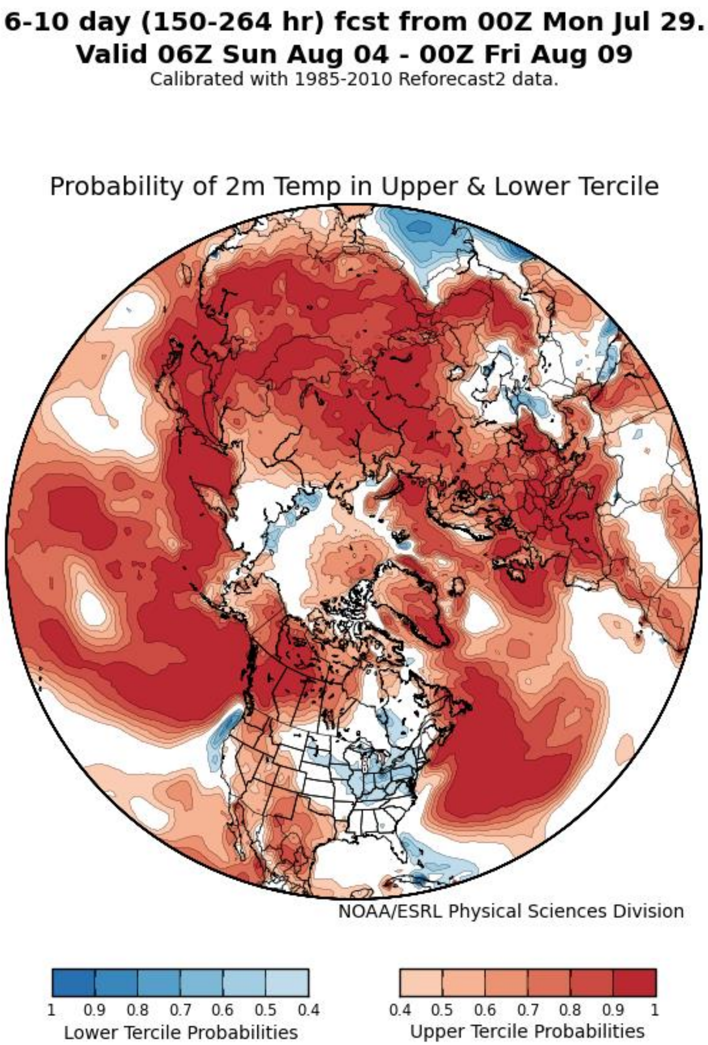
Forecast Period: 0-24 hrs

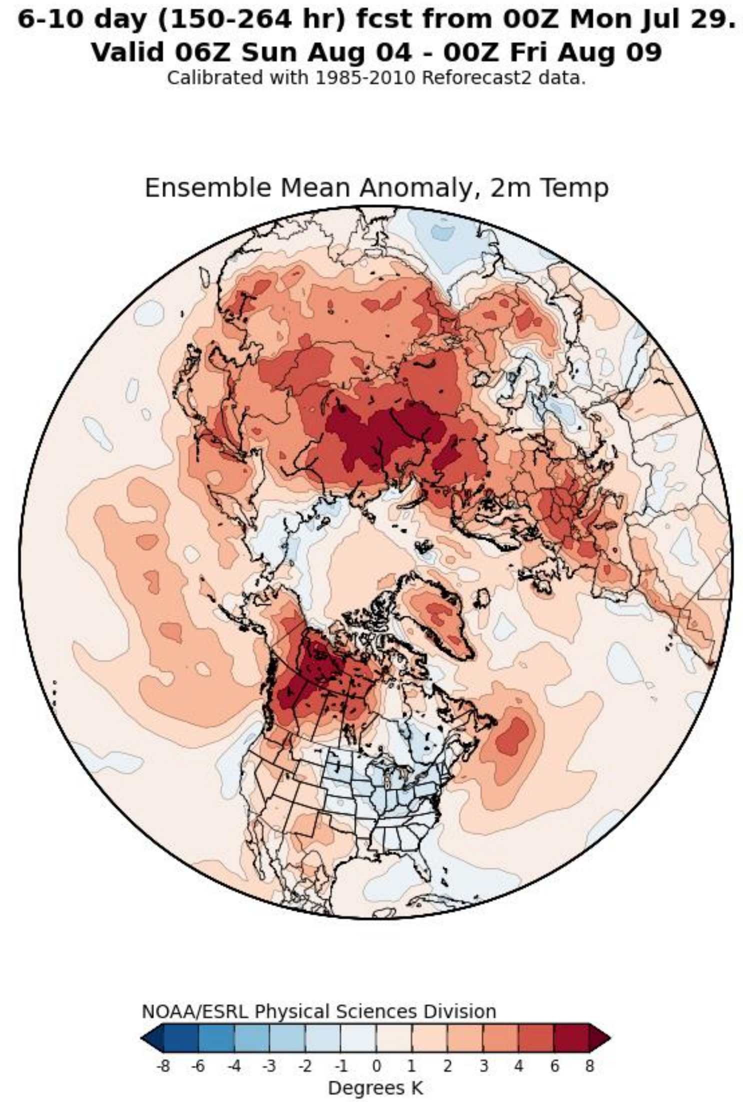
Plot Type: Deterministic Precip Amount

Get forecast plots

Our web site has experimental forecast products and permits downloads of the data

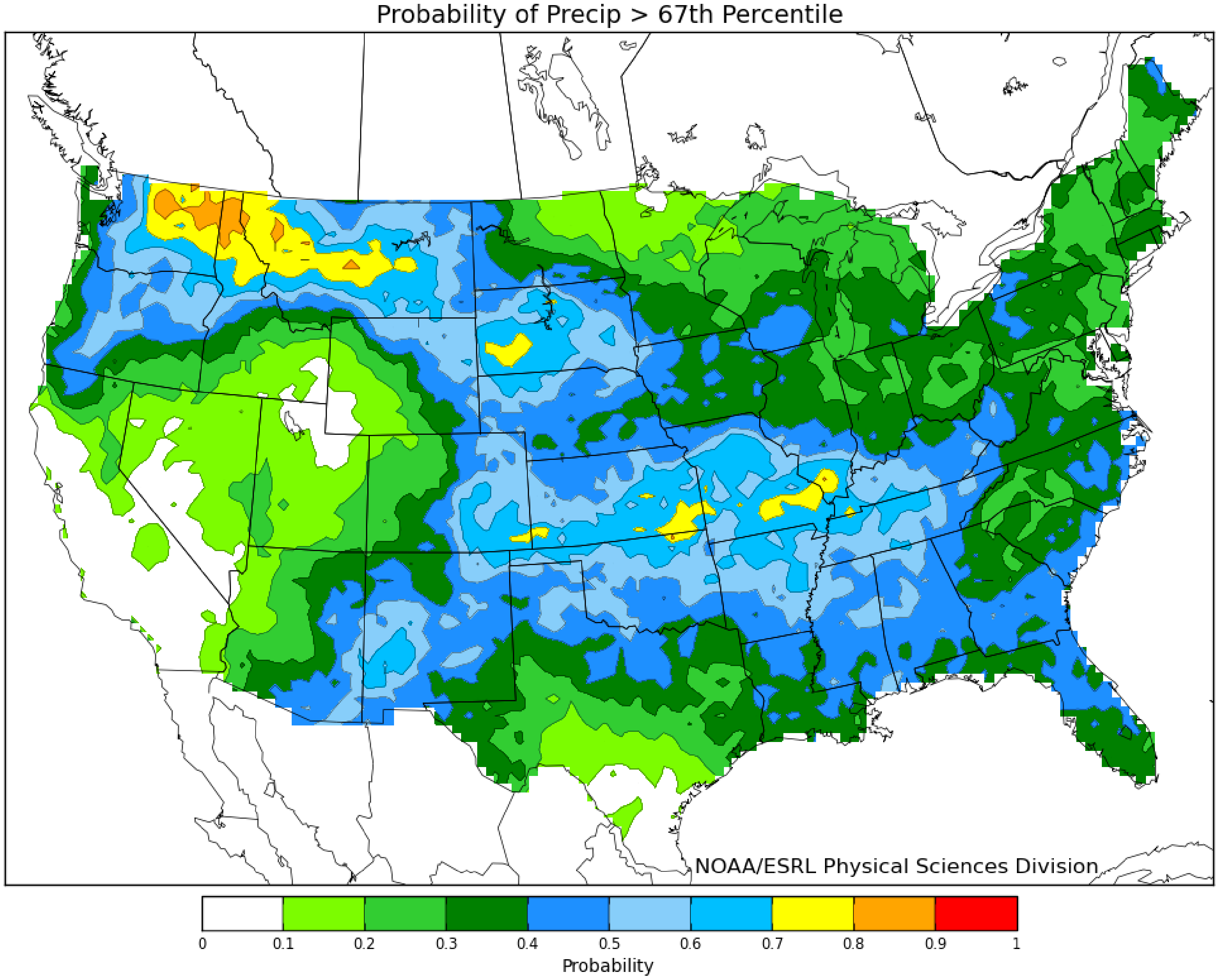
00Z Monday 29 July 2013 initialized 6-10 day forecast





120-240hr fcst from 00Z Mon Jul 29. Valid 00Z Sat Aug 03 - 00Z Thu Aug 08

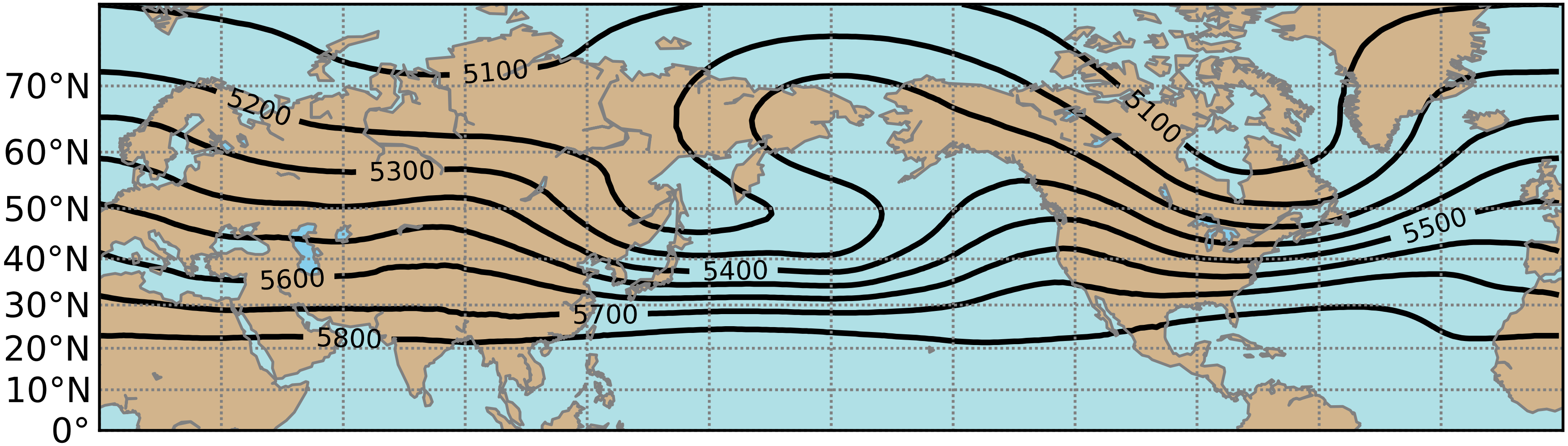
Calibrated with 1985-2010 Reforecast2 data.



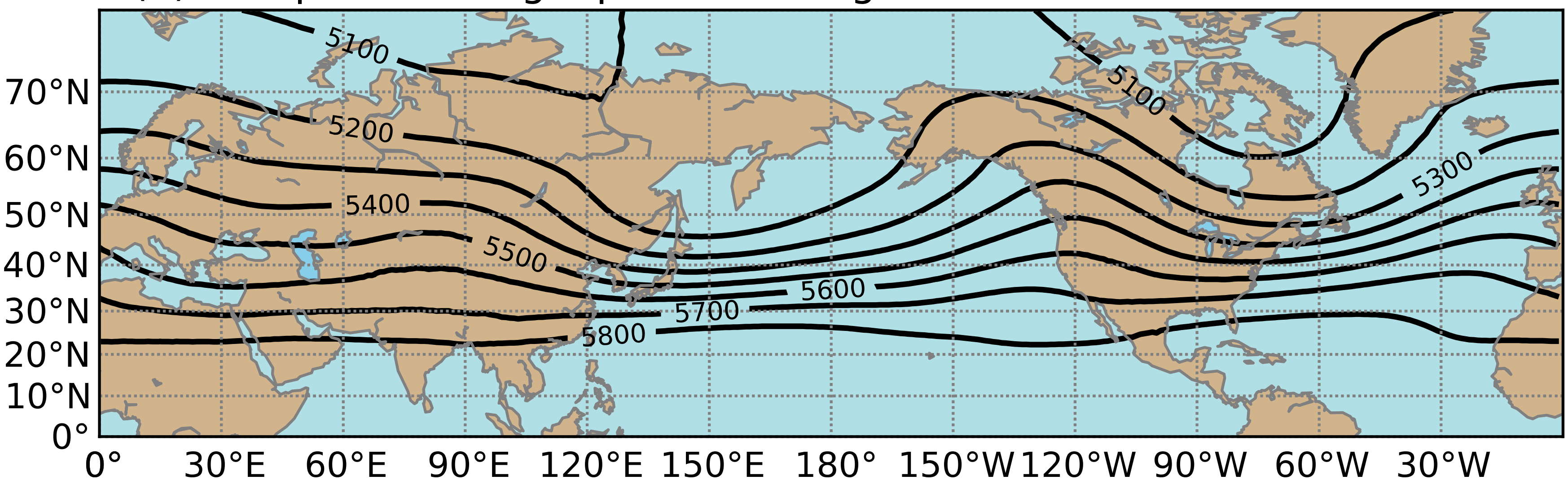
What else can one do with reforecasts?

Here we use them to examine the ability of the forecast model to skillfully predict low-frequency modes of variability and longer-lead forecasts (where large sample sizes are helpful).

(a) Composite 500 hPa geopotential height under block at Lon = 180E



(b) Composite 500 geopotential height under no block at Lon = 180E



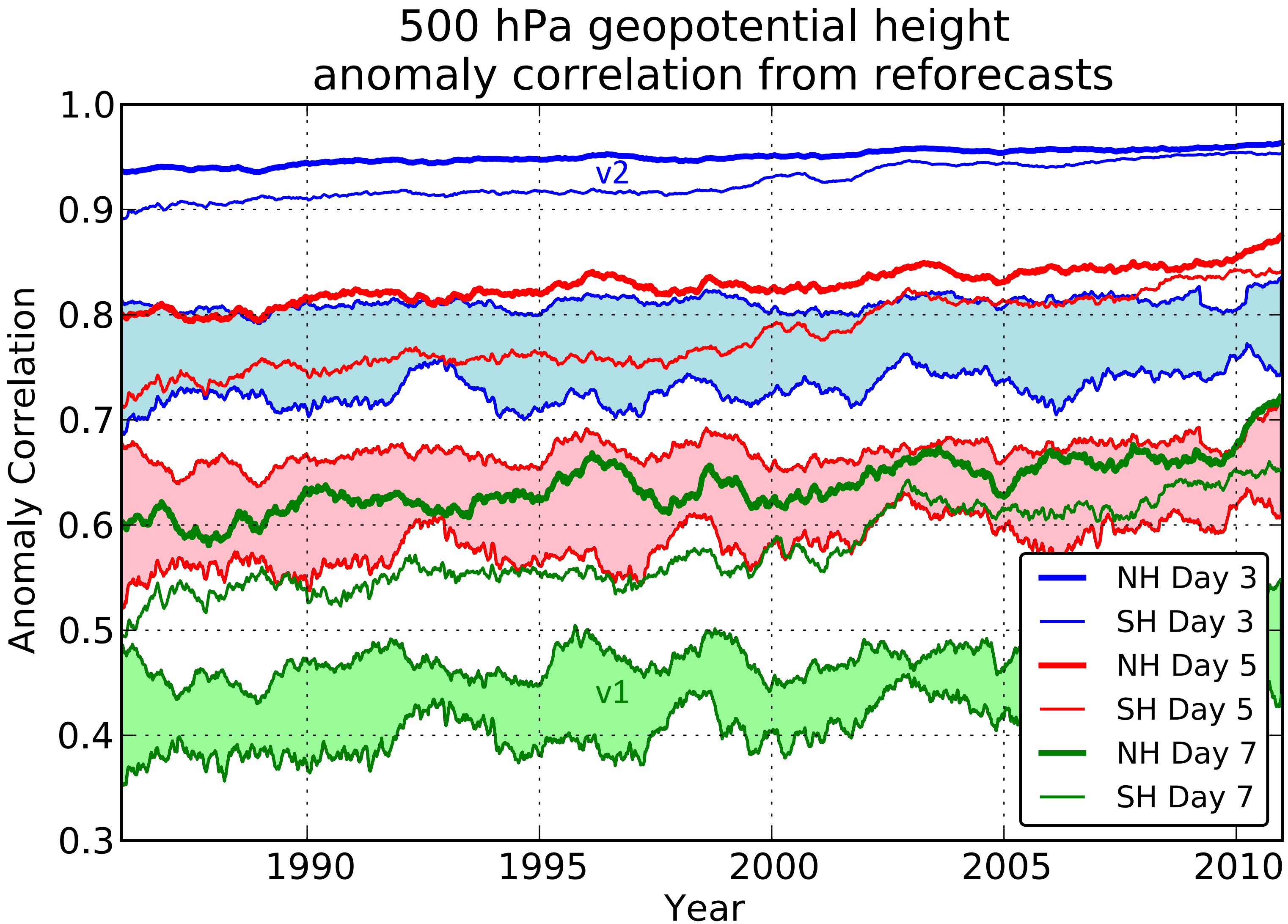
Dec-Jan-Feb 1985-2012 CFSR data. Blocks defined here by Tibaldi & Molteni algorithm.

Questions

- How well are blocking and MJO predicted in GEFS (reforecasts) at the medium range?
- Is blocking modulated by MJO, and is this modulation correctly forecast?

Data sets and methods

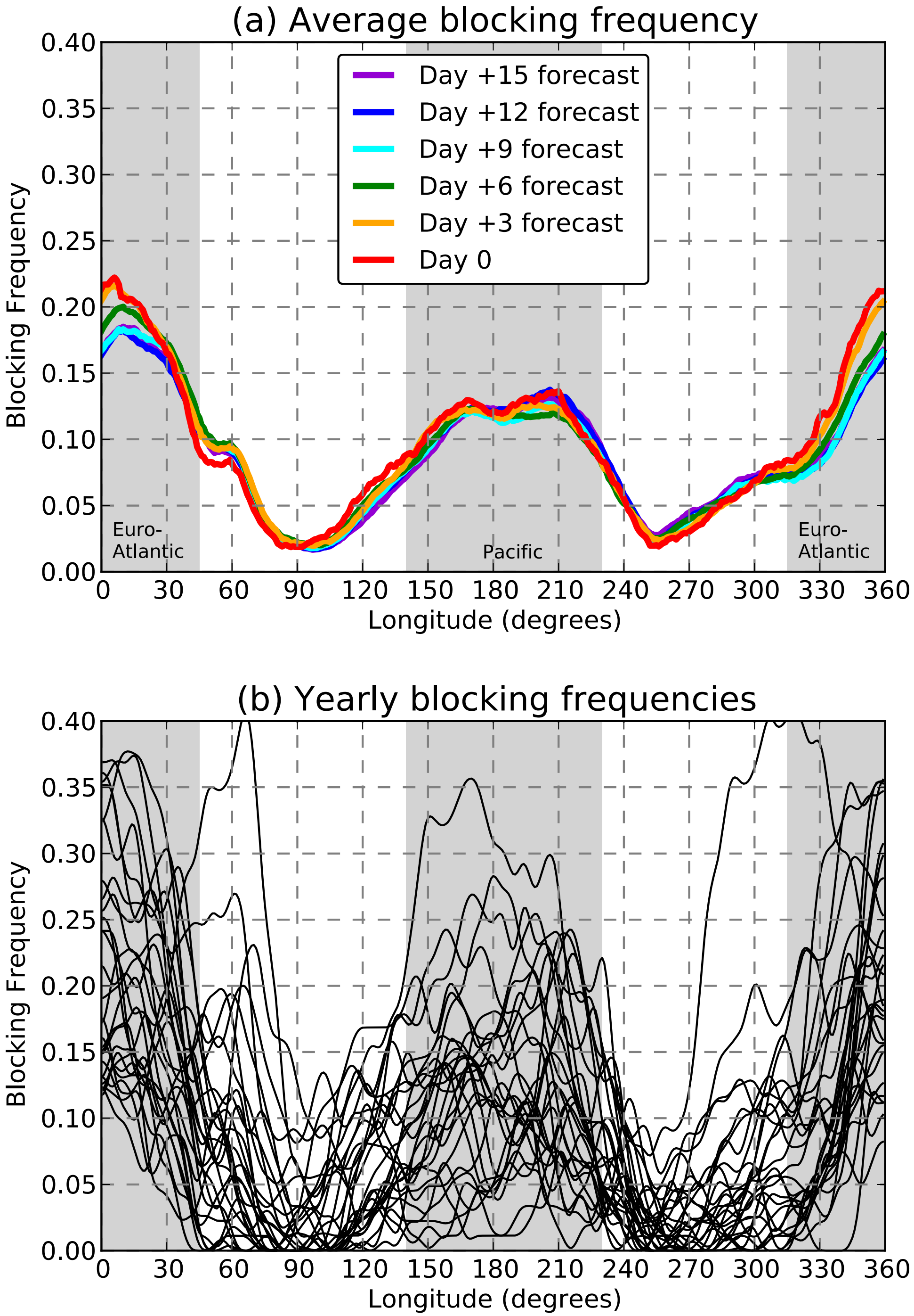
- GEFS Reforecast
  - Every day from 1985-present (DJF 1985-2012 data here).
  - 11 members, 1x daily (00 UTC). Forecasts to +16 days.
  - CFSR (prior to 2011), operational GSI (since 2011) + ensemble transform with rescaling (ETR) cycled initial conditions.
  - Model: 2012 GEFS configuration; T254L42 in week 1 (~40 km at 40°N), T190L42 in week 2.
  - Reforecast archive and documentation (incl. *BAMS* submitted article) at http://esrl.noaa.gov/psd/forecasts/reforecast2/
- MJO: RMM1 and RMM2 defined from CFSR reanalysis U850, U200, and OLR following standard Wheeler & Hendon algorithm.
- 1997-2012 daily 1-degree precip analyses from GPCP



(1) CFSR initial conditions used in GEFS generally improve over the decades, leading to slight improvements in GEFS skill.

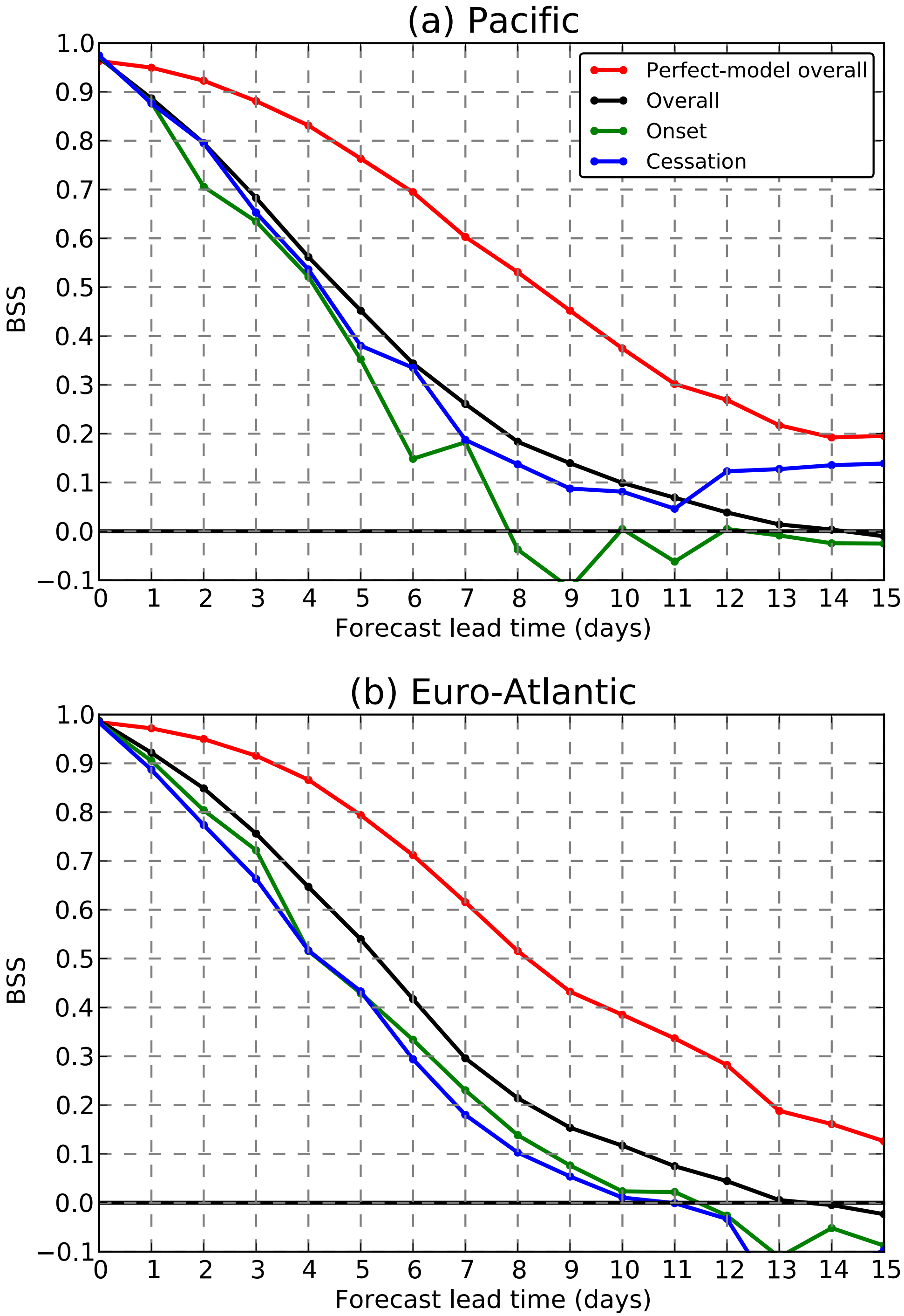
(2) About a +2 day improvement relative to 1998 GEFS T62 reforecasts.

Northern Hemisphere Dec-Jan-Feb 1985-2012 atmospheric blocking



Blocking frequency and inter-annual variability

Blocking as defined in Tibaldi and Molteni (1990) using Z500. Grey bands defines Euro/Atlantic and Pacific blocking sectors in subsequent plots.



Blocking skill in GEFS reforecasts

BSS (Brier skill score) as defined in supplementary slides.

Perfect model uses one member of ensemble as surrogate for analyzed.

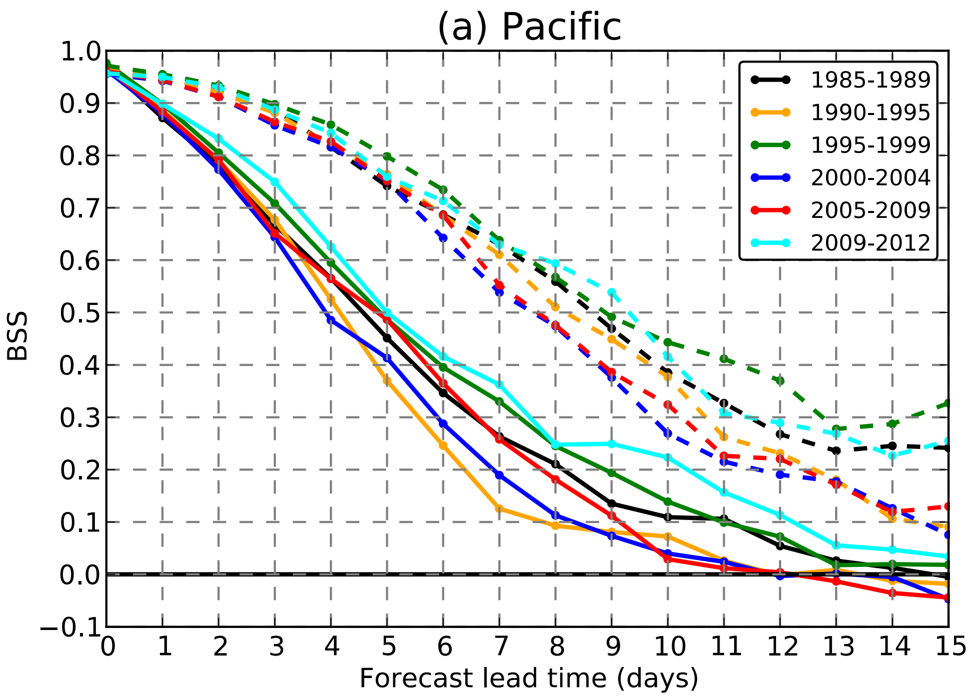
Real model: skill in blocking to ~13 days

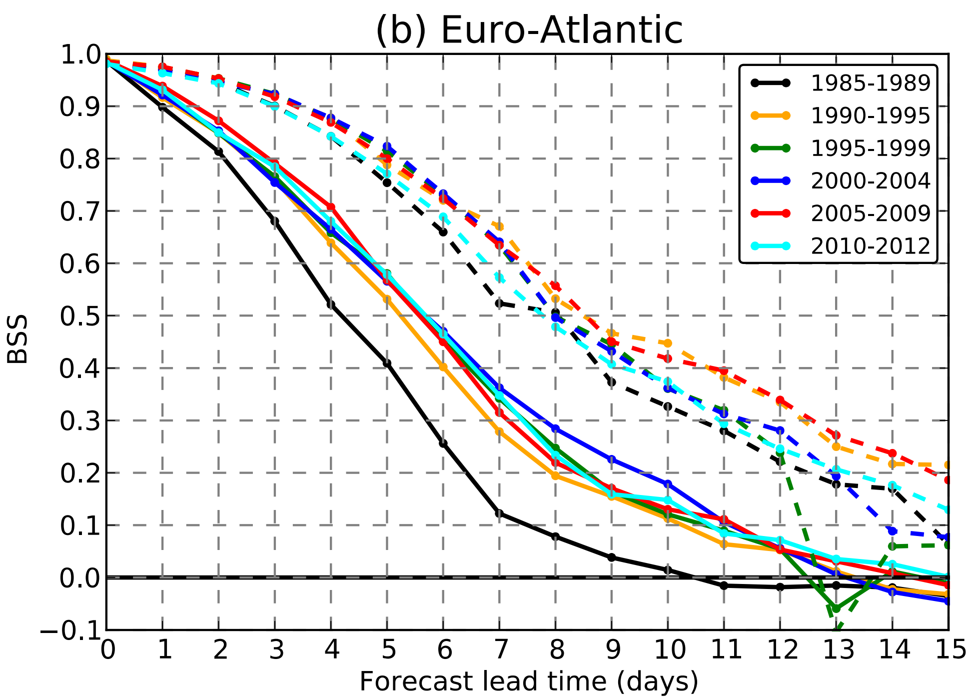
Perfect model: ~ 3-5 days longer skill.

Onset: date when there are more than 10 subsequent days where at least 20 degrees of longitude in a sector are blocked.

Cessation: date of end of that period.

Statistics include onset and previous 3 days, cessation and previous 3 days.





Blocking skill by half decade

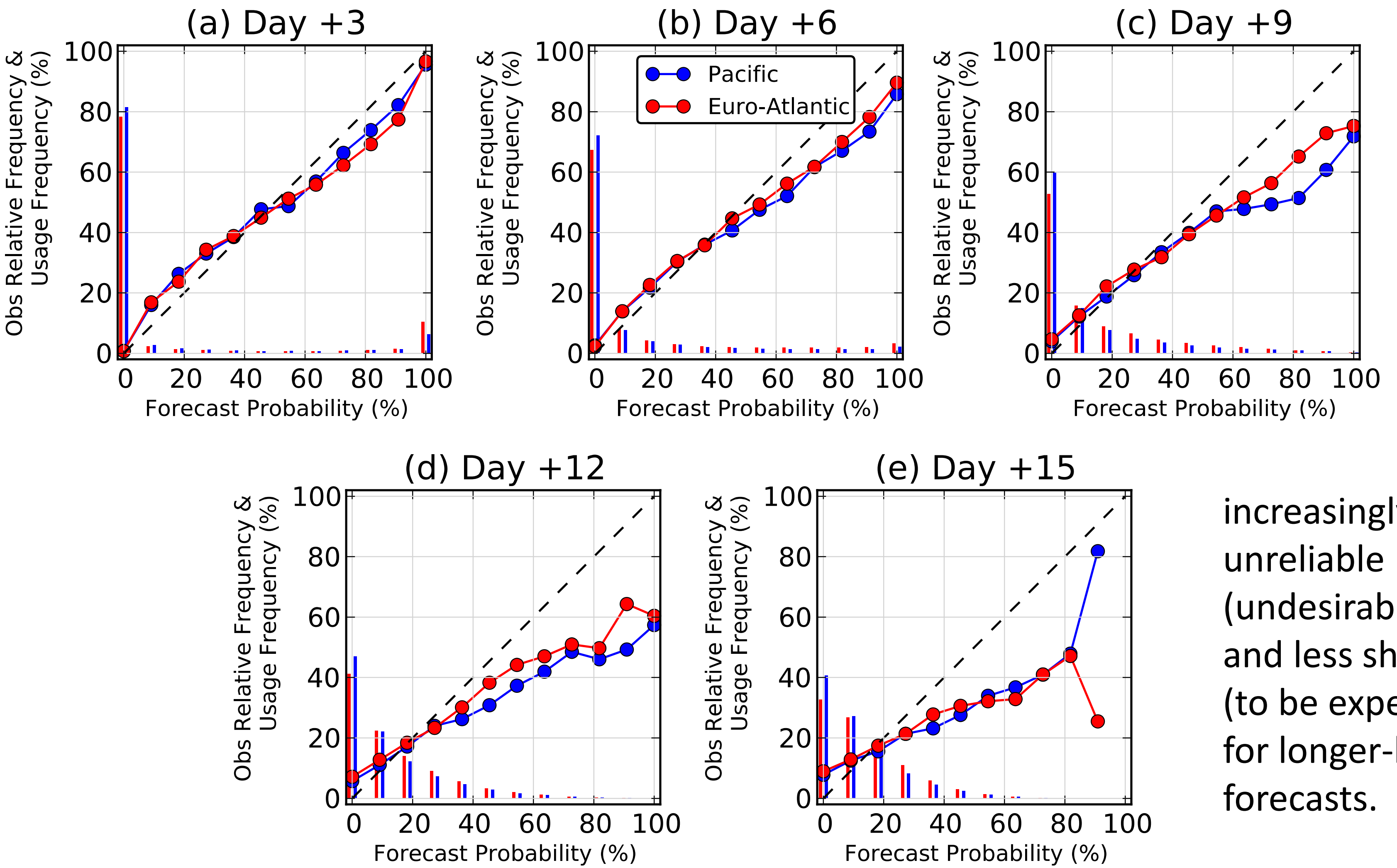
— actual skill.

--- perfect-model skill.

Decreased Atlantic sector skill in 1985-1989 period stands out.

Actual skill falls far short of perfect model skill. Some half-decadal variability due to natural variability, as seen in corresponding dashed lines.

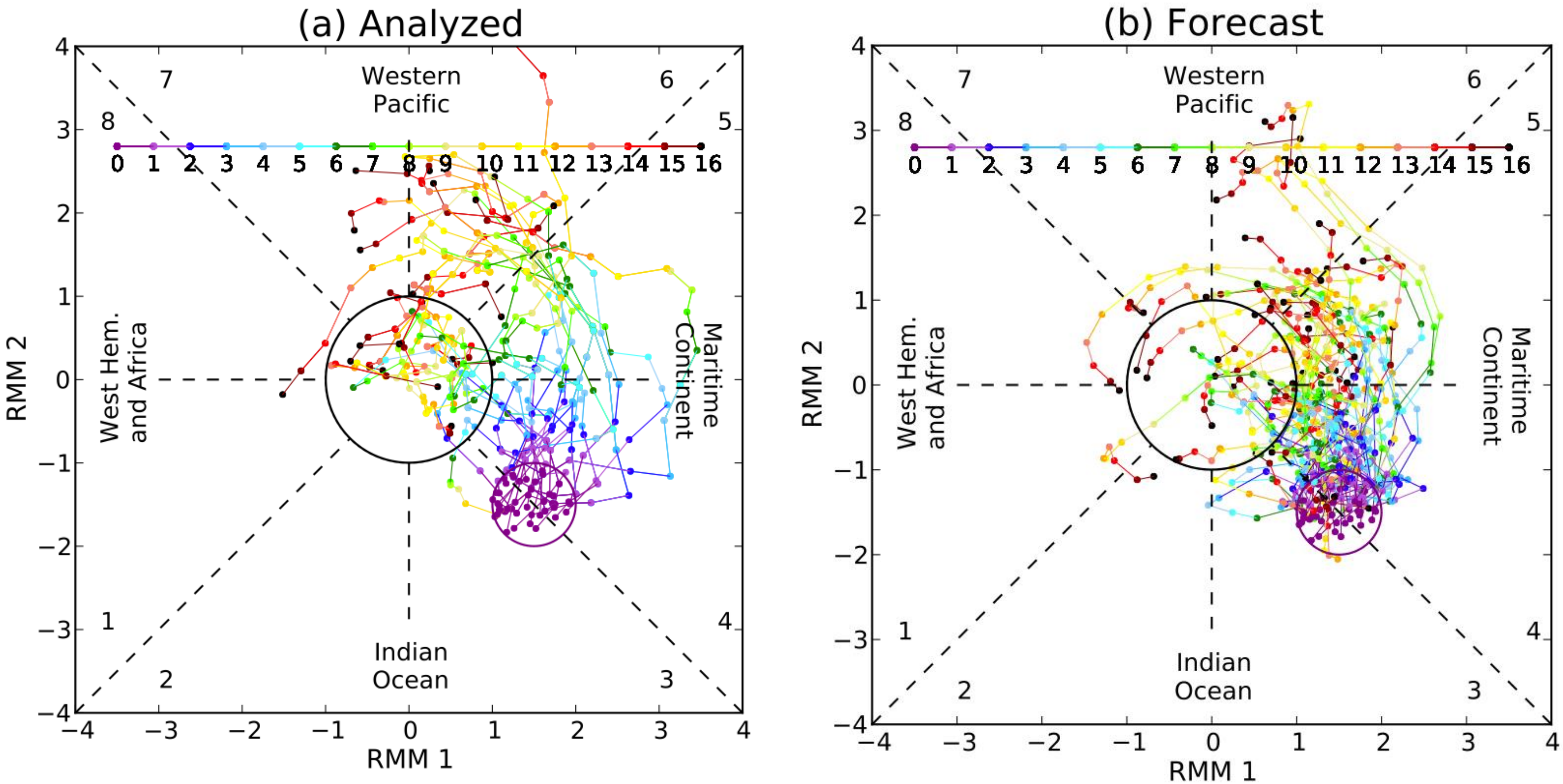
Reliability diagrams



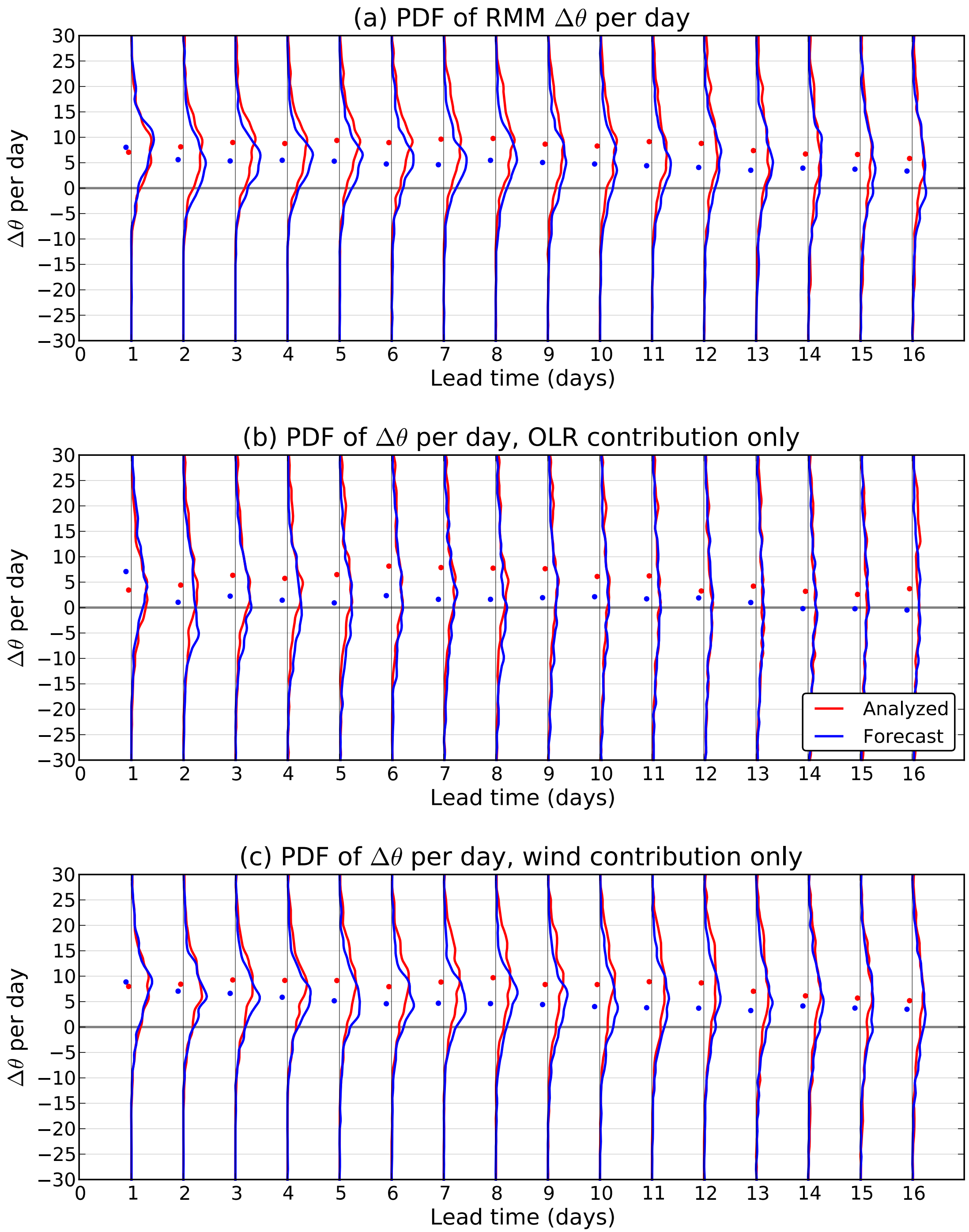
increasingly unreliable (undesirable) and less sharp (to be expected) for longer-lead forecasts.

MJO diagnostics

MJO, analyzed and deterministic forecast, E. Indian Ocean



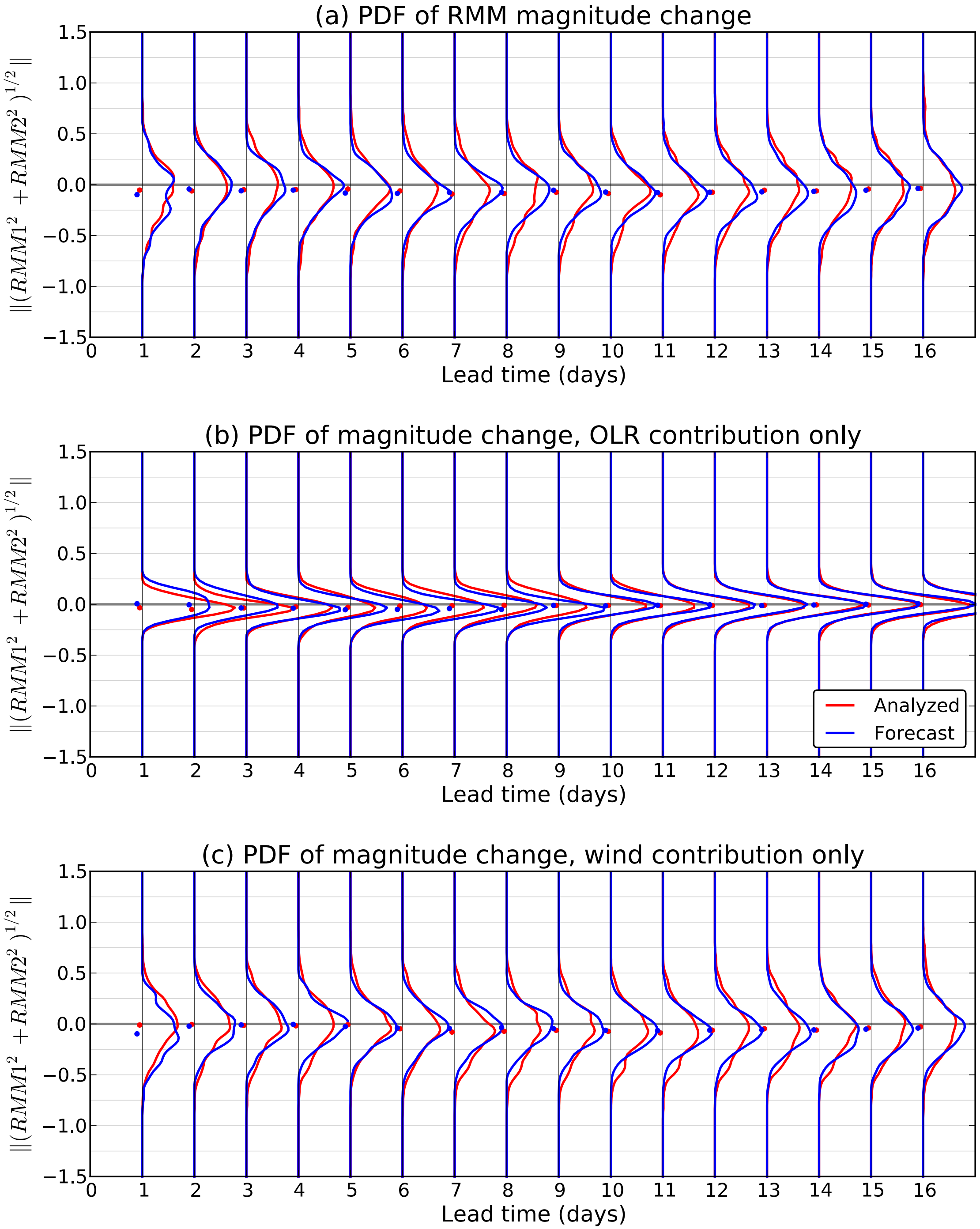
Dates selected (Dec-Jan-Feb 1985-2012) where initial state was inside purple circle. Examine (RMM1, RMM2) phase plot for analyzed and forecast.



Propagation characteristics of MJO phase for strong MJO (magnitude > 1.0, OLR magnitude > 0.5, RMM2 < 0)

PDF shows change relative to data from a day prior, analyzed and ensemble members.

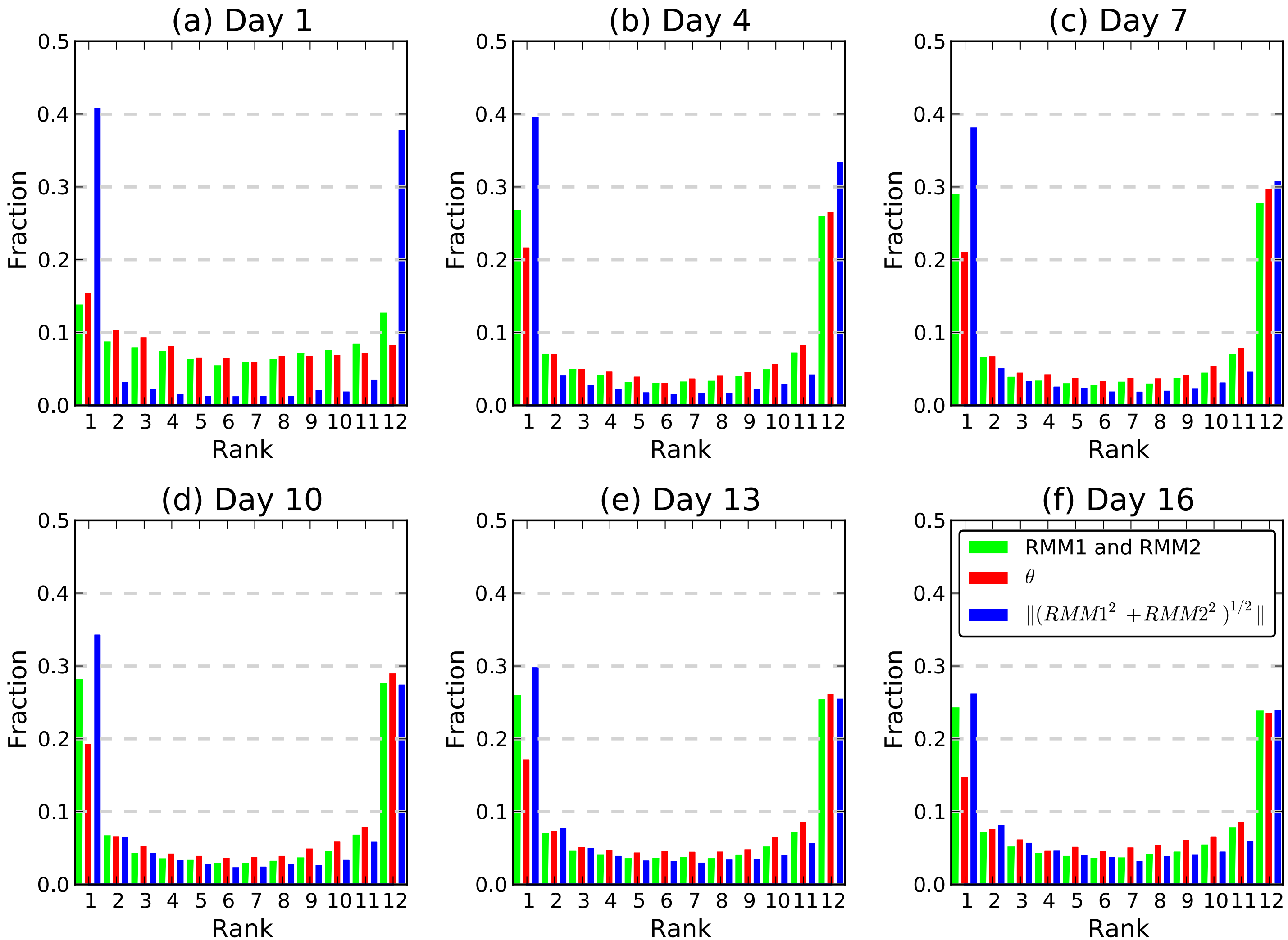
MJO forecasts propagate more slowly than analyzed, and more so for OLR component than wind components.



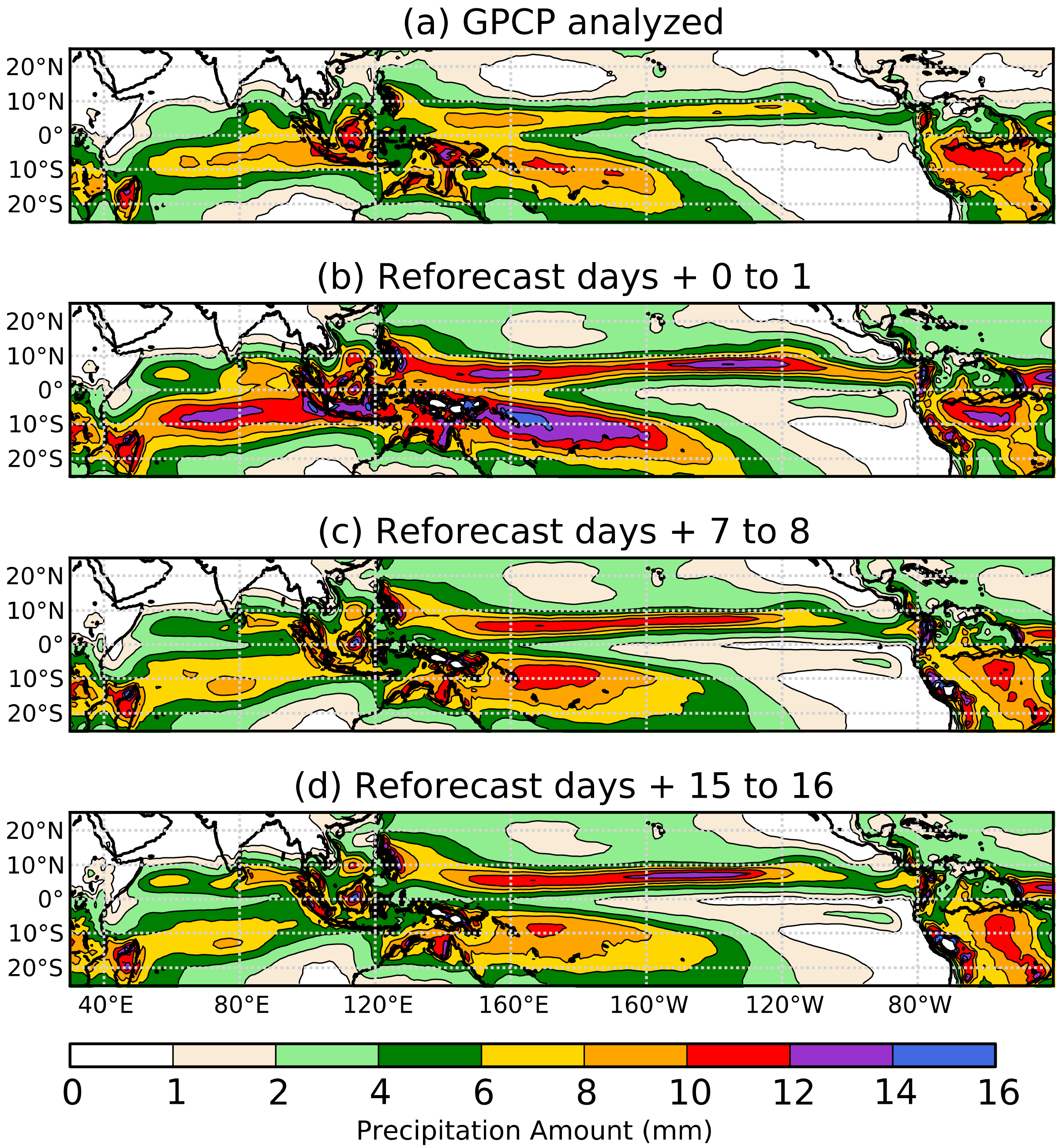
Propagation characteristics of MJO magnitude for strong MJO (magnitude > 1.0, OLR magnitude > 0.5, RMM2 < 0)

Forecast distribution is a bit more peaked, indicating that forecasts are more consistent in time in their magnitude than with analyzed conditions.

Rank histograms, RMM1 and RMM2 composited



GEFS reforecasts quickly develop insufficient spread and/or biased mean.
RMM most under-spread and/or biased at the medium range.
Especially insufficient variety of forecasts of MJO magnitude, even at short leads.

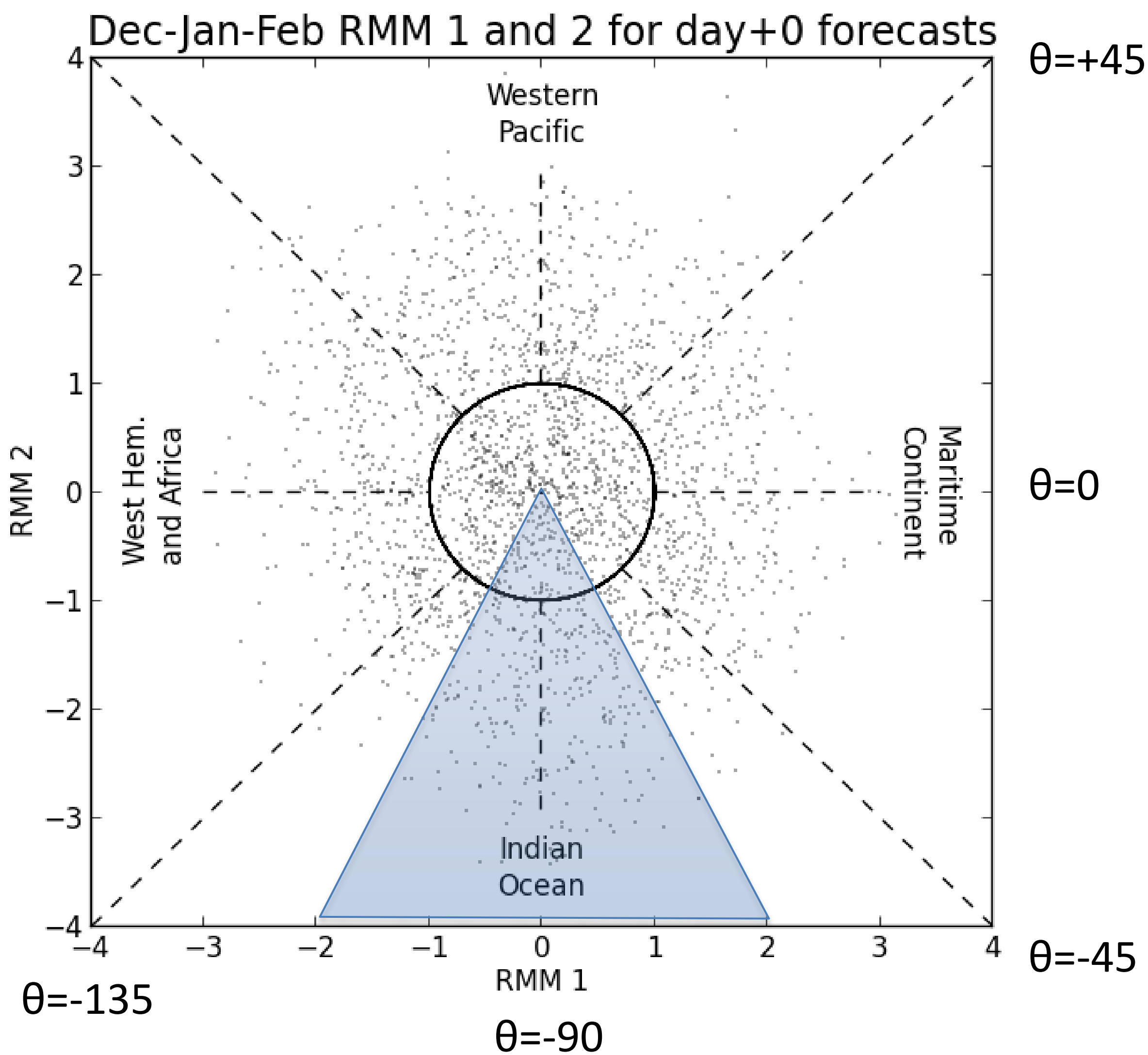


Daily rainfall climatology

Large over-forecasting of precipitation on first day of forecast. Patterns of forecast precipitation at extended leads somewhat off, e.g., SPCZ not connected as well to ITCZ.

MJO – blocking interactions

My method of quantifying MJO phase

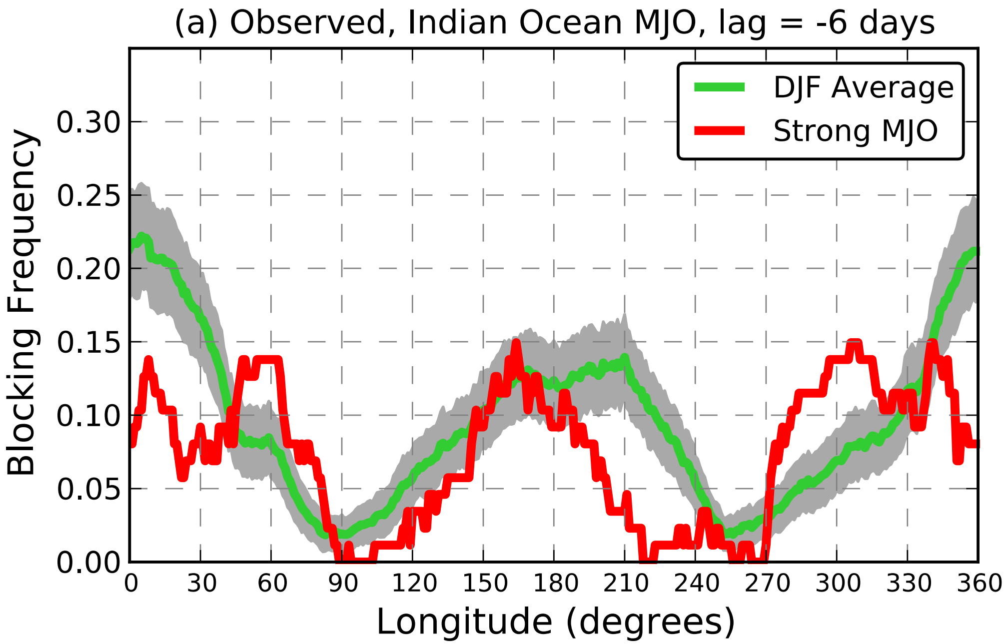


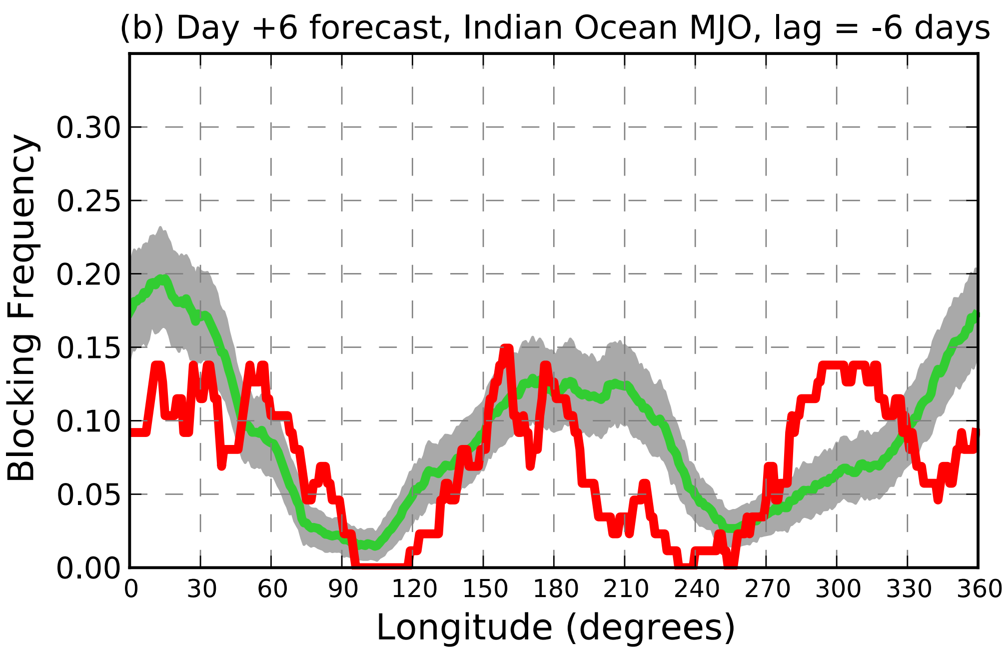
In subsequent plots you'll see I refer to the phase of MJO by its angle from x axis, a θ in conventional polar coordinates.

When examining statistics for $\theta=\theta_0$, I use RMM 1/2 samples with associated θ_0 +/- 22.5 degrees.

Example below for $\theta_0=-90$ uses samples in blue cone.

A "strong" MJO is in the top 25% of RMM 1/2 amplitudes within the cone.



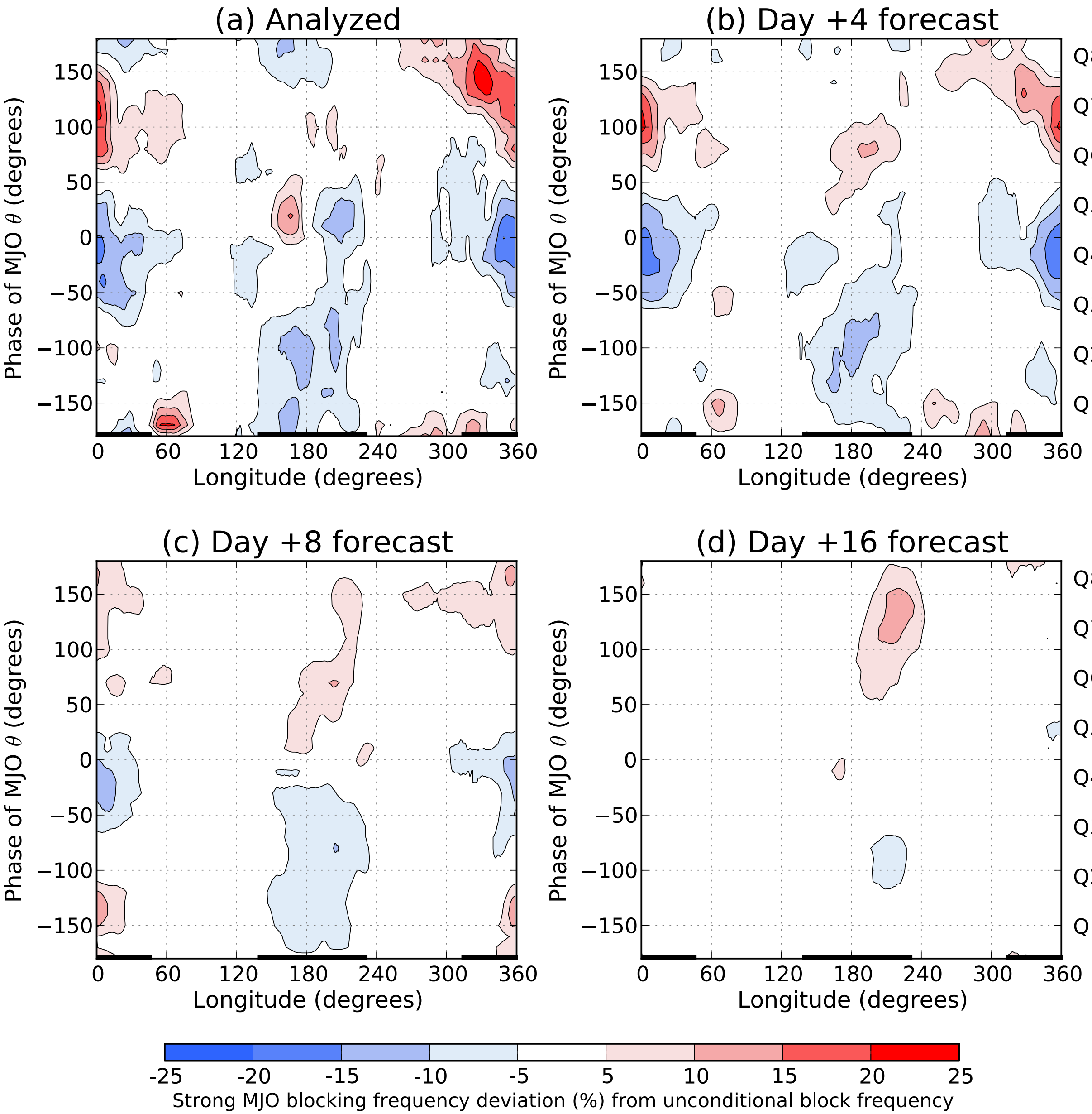


Change in blocking frequency under strong Indian Ocean MJO

Shaded areas are confidence 5/95% confidence intervals.

Suppression of blocking frequency in the east Pacific and Atlantic under strong MJO. Day +6 GEFS nicely replicates this suppression.

Blocking MJO relationship with strong MJOs



Top left panel shows, as the phase of a strong MJO varies along y axis, the change in blocking frequency from the overall climatological frequency for each given longitude (x axis). Note, for example, that as the phase of the MJO goes from 0° (Maritime continent) to 120°, Atlantic blocking frequency changes from suppressed to much more active than normal. This pattern is largely replicable in day + 4 forecasts, but much less so in day + 8 and day +16 forecasts. The GEFS is not replicating the blocking response to MJO forcing.

Conclusions

- Blocking:
  - Some skill, but much less than perfect model. For intraseasonal, take note at how little skill there is by week +2
  - Reasonable replication of blocking climatological frequencies in forecasts.
- MJO:
  - Forecasts decrease in amplitude, slow down relative to analyzed.
  - Ensemble forecasts under-dispersed/biased, especially for magnitude.
  - Some skill, though, especially for high amplitude MJOs
- Blocking and MJO
  - Blocking frequency changes in response to active MJO not correctly forecast except with shorter-term forecasts.
- Acknowledgments: Steve Colucci, Klaus Weickmann, Jeff Whitaker, Jon Gottschalck.

Define BSS for evaluating blocking skill

- The blocking Brier Skill score is calculated after summing forecast and climatological Brier scores over the relevant longitudes in either the Pacific or Atlantic basins, respectively, then averaged. For example (Pac):

$$BSS = 1.0 - \frac{BS_{forecast}}{BS_{climo}}$$

$$BS_{forecast} = \sum_{l_p=1}^{nlons} \sum_{i=1}^{ndates} \left(p_i^{forecast}\left(l_p\right) - o_i\left(l_p\right) \right)^2$$

$$BS_{climo} = \sum_{l_p=1}^{nlons} \sum_{i=1}^{ndates} \left(p_i^{climo}\left(l_p\right) - o_i\left(l_p\right) \right)^2$$

$$o_i\left(l_p\right) = \left\{ \begin{array}{cc} 1 & if\ blocked \\ 0 & if\ unblocked \end{array} \right\}$$

$$p_i^{forecast}\left(l_p\right) = ensemble - based\ probability\ of\ block\ for\ this\ longitude$$

$$p_i^{climo}\left(l_p\right) = climatological\ probability\ of\ block\ for\ this\ longitude$$

Computing the CRPSS of GEFS RMM1 and RMM2 forecasts

- CRPSS = 1 – CRPS(forecast) / CRPS(climatology)

$$CRPS(forecast) = \sum_{i=1}^{ndates} \sum_{j=1}^{ncats} \frac{1}{ncats} \left(\Phi_{forecast}\left(i, x(j)\right) - \Phi_{analyzed}\left(i, x(j)\right) \right)^2$$

$$CRPS(climo) = \sum_{i=1}^{ndates} \sum_{j=1}^{ncats} \frac{1}{ncats} \left(\Phi_{climo}\left(i, x(j)\right) - \Phi_{analyzed}\left(i, x(j)\right) \right)^2$$

$$x(1) = -5.0, \quad x(2) = -4.9, \quad \ldots, \quad x(ncats) = +5.0$$

$$\Phi(\cdot) = \textit{cumulative distribution function for either RMM1 or RMM2}$$

- $\Phi(\cdot)$ estimated from normal distribution fit to sample mean and standard deviation.

Blocking computation method: follows Tibaldi and Molteni, 1990 *Tellus*

(1950). The procedure we have applied is as follows: the 500 hPa field is firstly evaluated on a 4° by 4° regular latitude–longitude grid covering the Northern Hemisphere. Then the geopotential height gradients GHGS and GHGN (referring to middle and high latitudes respectively) are computed for each longitude point of the grid:

$$GHGS = \frac{Z(\phi_o) - Z(\phi_s)}{(\phi_o - \phi_s)},$$

$$GHGN = \frac{Z(\phi_n) - Z(\phi_o)}{(\phi_n - \phi_o)},$$

where

$$\phi_n = 80^\circ N + \Delta,$$
$$\phi_o = 60^\circ N + \Delta,$$
$$\phi_s = 40^\circ N + \Delta,$$
$$\Delta = -4^\circ, 0^\circ \text{ or } 4^\circ.$$

A given longitude is then defined as "blocked" at a specific instant in time if the following conditions are satisfied for at least one value of Δ:

(1) $GHGS > 0$,

(2) $GHGN < -10$ m/deg lat.

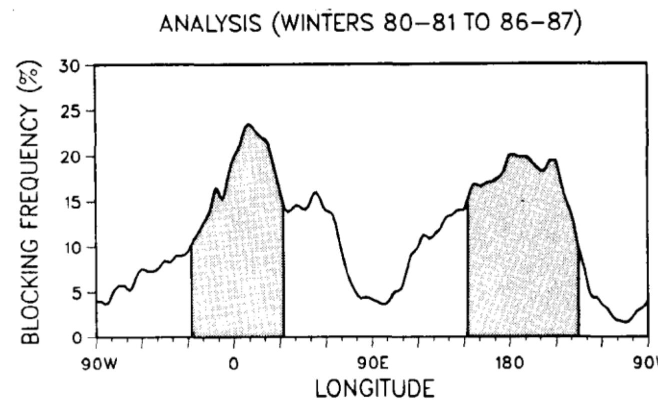


Fig. 1. Percentage frequency of blocking (objectively defined in Section 2) as a function of longitude and computed on all ECMWF daily objective analyses of our database.

There are alternatives, such as PV-based index by Pelly and Hoskins. While these may have some advantages, this old standard used hereafter.

MJO task force data

Center	Model	Data Stream ID	Ensemble Members	Forecasts Start	Length (Days)	Realtime Data FTP	Version 1 Plots	Model Climatology
NCEP	GFS EPS T126[1]	NCPE	21	Nov 2007	15	-----	Yes	No
NCEP	GFS T382[1]	NCPO	1	Jan 2008	15	-----	Yes	No
NCEP	CFS T62[1]	NCFS	4	Jan 2007	40	-----	Yes	Yes
CMC	GEMDM_400x200[2]	CANM	20	Jun 2008	16	Yes	Yes	No
UKMO	MOGREPS[3]	UKMA	1	Oct 2007	15	Yes	Yes	No
UKMO	MOGREPS[3]	UKME	23	Oct 2007	15	Yes	Yes	No
ABOM	GASP T239[4]	BOMA	1	Jan 2008	10	Yes	Yes	No
ABOM	GASP EPS T119[4]	BOME	32	Aug 2008	10	Yes	Yes	No
ABOM	POAMA1.5bT47[4]	BOMC	1	Jan 2008	40	Yes	Yes	No
ABOM	POAMA1.5T47[4]	BOMH	1	Jan 2008	40	Yes	No	Yes
ECMWF	VAREPS T299/T255[*]	ECMF	51	Jun 2008	15	Yes	Yes	No
ECMWF	VAREPS T299/T255[*]	ECMM	51	Jun 2008	15	Yes	Yes	Yes
ECMWF	SFSv3 T159[*]	EMON	51 (W)	Jun 2008	32	Yes	Yes	No
ECMWF	SFSv3 T159[*]	EMOM	51 (W)	Jun 2008	32	Yes	Yes	Yes
JMA	GSM WEPS T319[6]	JMAN	51	Nov 2008	9	Yes	Yes	No
CPTEC	GWEFS T126[7]	CPTC	15	Feb 2009	15	Yes	Yes	No
IMD	NCMRWF T254[8]	IMDO	1	Jun 2009	7	Yes	Yes	No
IMD	NCMRWF EPS T80[8]	IMDE	8	------	7	No	No	No
FNMOC	NOGAPS T119[9]	NGAP	10	------	10	No	No	No
TCWB	CWB EPS T119^	TCWB	1	Oct 2009	40	Yes	Yes	No

MJO deterministic verification metrics

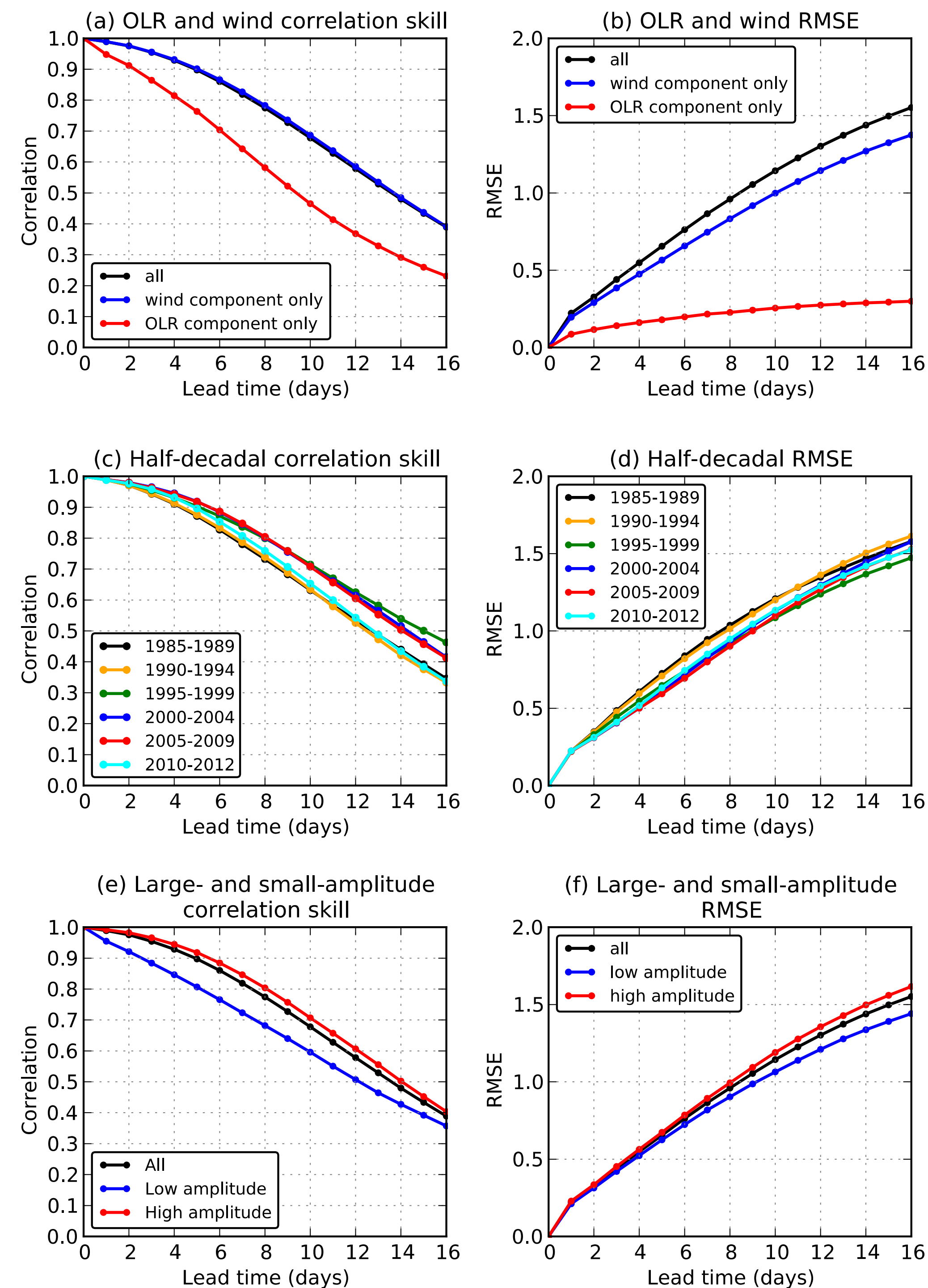
$$\mathrm{COR}(\tau) = \frac{\sum_{i=1}^{N}[a_{1i}(t)b_{1i}(t) + a_{2i}(t)b_{2i}(t)]}{\sqrt{\sum_{i=1}^{N}[a_{1i}^2(t) + a_{2i}^2(t)]}\sqrt{\sum_{i=1}^{N}[b_{1i}^2(t) + b_{2i}^2(t)]}},$$

where $a_{1i}(t)$ and $a_{2i}(t)$ are the observed RMM1 and RMM2 at day t, and $b_{1i}(t)$ and $b_{2i}(t)$ are their respective forecasts, for the ith forecast with a τ-day lead. Here, N is the number of forecasts.

COR(τ) measures the skill in forecasting the phase of the MJO, which is insensitive to amplitude errors. COR(τ) is equivalent to a spatial pattern correlation between the observations and the forecasts when they are expressed by the two leading combined EOFs.

$$\mathrm{RMSE}(\tau) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\{[a_{1i}(t) - b_{1i}(t)]^2 + [a_{2i}(t) - b_{2i}(t)]^2\}}.$$

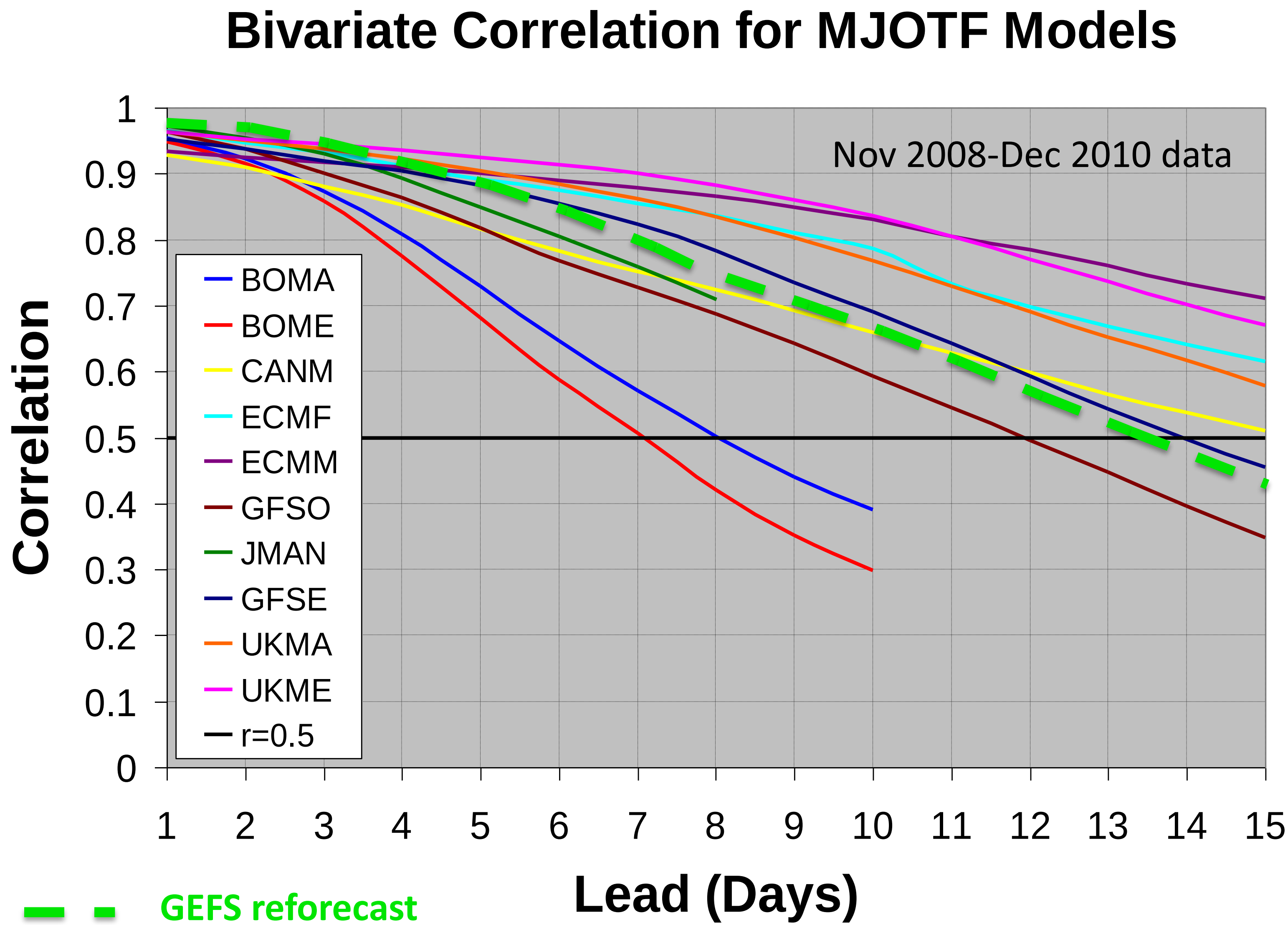
from Lin et al., Nov 2008 *MWR*.



Bi-variate RMM1 and RMM2 correlation and RMSE

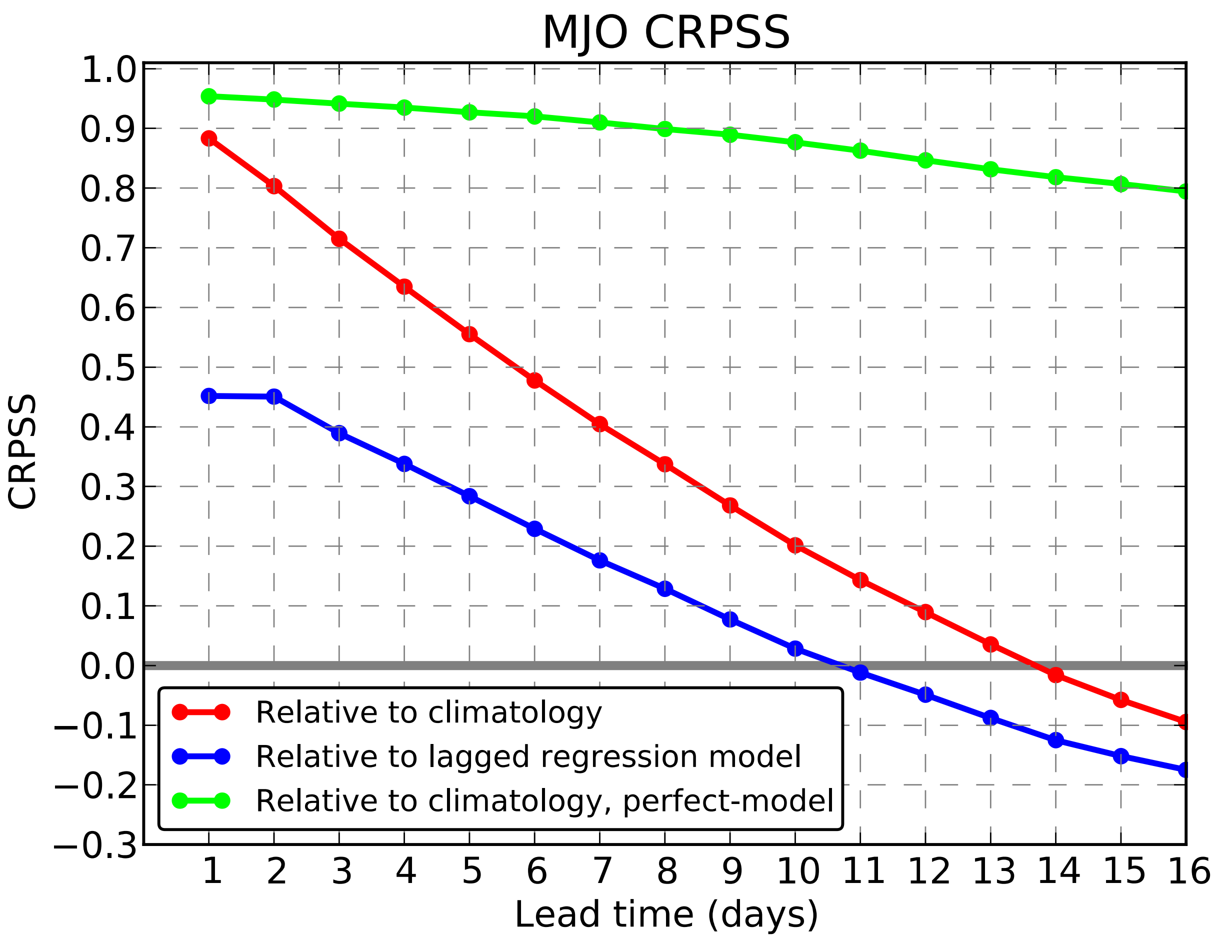
Low amplitude:
$\sqrt{(RMM1^2+RMM2^2)} < 1$
High amplitude:
$\sqrt{(RMM1^2+RMM2^2)} \geq 1$

Comparing against MJO task force data…



c/o Jon Gottschalk

Probabilistic forecast verification: CRPSS



Method for computing CRPSS discussed in supplementary slides. References are climatology and a regression model based on lagged persistence using day 0, -5, -10, -15, -20, and -25 RMM1 and RMM2 values.

The extremely high skill of the perfect-model scenario likely exaggerates the best case; as seen in rank histograms, there is undue consistency among ensemble members. This inflates perfect-model skill.

Z500 anomalies under strong (6-day lagged) Indian Ocean MJO